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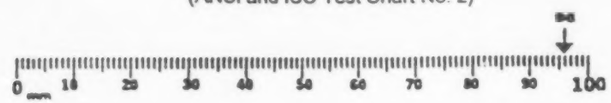

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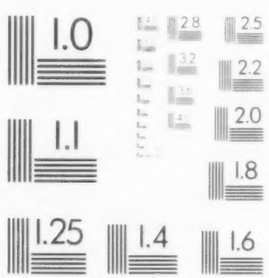

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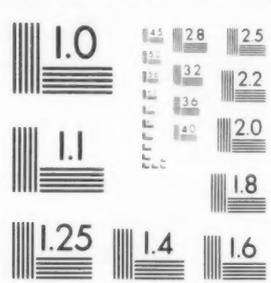

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Aggregate Fluctuations, Monetary Policy and Nominal Wage Rigidities in a New-Classical Setting: Results for Canada

by

Humam Sakhnini

Working Paper No. 95-04

The author wishes to thank Craig Burnside, Barry Cozier, Steven James, Mike Kennedy, Benoît Perron, Munir Sheikh, and seminar participants at the Department of Finance for their useful comments. An earlier version of this paper was presented at the session on labour market issues at the CEA meetings in Calgary, June 10, 1994. Any remaining errors in this paper are the sole responsibility of the author.

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ABSTRACT

Recent work by Lucas (1989), King (1991), and Cho (1993) has incorporated nominal wage and price rigidities into a new-classical framework as a possible additional explanation for business cycles. This paper features a model of optimizing agents in a stochastic general equilibrium framework where the shocks to the economy come from technology, innovations in monetary policy, and innovations in fiscal spending. Agents choose to enter wage contracts for periods of time based on the expected market clearing price of labour in those periods, and therefore labour markets do not clear every period. The available literature contains work that utilizes U.S. data. Our model contributes to the literature by measuring the success of this class of models in explaining Canadian business cycles and in outlining the effects of wage rigidities on the effectiveness of monetary policy.

RÉSUMÉ

Lucas (1989), King (1991) et Cho (1993) ont ajouté au modèle nouveau-classique les rigidités des prix et des salaires nominaux comme explications additionnelles des cycles d'affaire réels. Ce travail présente un modèle d'équilibre général stochastique où les chocs proviennent de la technologie de production et des innovations dans les politiques fiscales et monétaires. Les agents économiques choisissent de fixer leur salaire par contrat pour une certaine période en se basant sur le salaire d'équilibre anticipé au cours de cette période. Par conséquent, le marché du travail n'est pas en équilibre en tout temps. Les études empiriques sur ce type de modèle ont toujours utilisé, jusqu'à maintenant, des données américaines. Ce travail innove en vérifiant la capacité de ce type de modèle à prédire les cycles monétaires canadiens et en soulignant les effets de la rigidité des salaires nominaux sur l'efficacité de la politique monétaire.

1. Introduction

Monetary theory may be one of the most researched topics in macroeconomics, but surprisingly, no general agreement has been reached among economists regarding the impact of monetary policy on real economic variables. Historically, the division has followed the traditional Keynesian-Classical split, where Keynesian models predicted that anticipated monetary shocks could affect real variables, while the classical/monetarist models predicted that such shocks would affect nominal but not real variables. The current debate continues along similar lines. Although empirical testing is usually the decisive approach in determining the accuracy of competing theories, empirical studies of the real effects of money have produced no clear results.

Currently, the popular economic intuition is that the economy closely follows the Keynesian framework in the short to medium run, but is governed by the classical paradigm in the long run. That is, monetary shocks are believed to cause an expansion in output in the short to medium run, but the effect dissipates in the long run. When long periods of time are considered, steady-state output, capital and labour are believed to be determined according to neoclassical fundamentals. Accordingly, the only shocks that can affect long-run steady-state values are real shocks -- for example, those generated by advances in labour-augmenting technological progress. This dichotomy has been recently alluded to by King (1991), Lucas (1989), McCallum (1993), Cho (1993), Ambler and Phaneuf (1992) and others. However, it is only until recently that internally-consistent theoretical models that can replicate this popular view have begun to emerge.

The aim of this paper is to study the impacts of monetary policy on real variables in the economy by developing a general equilibrium model with stochastic growth which incorporates fiscal policy and monetary policy variables and staggered wage contracts. In this setting, firms and workers agree on nominal wages in advance, based on their rational expectations of the wages that would clear the markets. When fiscal, monetary or technology shocks hit the economy, their effects on the labour market are pronounced due to the slow adjustment of wages. In the absence of wage contracts and the monetary variables, the model is a real business cycle (RBC) model like that of Christiano and Eichenbaum (1992) who assume perfectly flexible real wages and labour market clearing. Christiano and Eichenbaum show that their model generates first and second moments for output, investment, and consumption that closely match those observed in the U.S. economy over the 1955 to 1988 period, but fails to reproduce stylized labour market facts such as the low correlation between average productivity and hours worked -- a shortcoming common to the RBC literature.

This paper incorporates the New-Keynesian features of nominal wage contracts into the general equilibrium framework, while retaining the rigorous stochastic optimizing features of the RBC literature. Similar work which incorporates nominal rigidities into a stochastic general equilibrium framework has recently begun to emerge. Hairault and Portier (1993), Cho (1993), Ambler and Phaneuf (1992), King (1991), and Lucas (1989) have all presented models where nominal wage and price rigidities were combined into the new-classical general equilibrium models. Although these papers have presented a variety of models and techniques, the general results have been encouraging, in that the fit of these models is better than the fully flexible RBC models, especially in mimicking labour market data. More dramatically, although RBC research has been intensely pursued since the beginning of the 1980s, recent work in incorporating rigidities presents an important leap in bringing these models closer to becoming relevant policy analysis tools.

In historical perspective, synthesizing classical and Keynesian ideas is not new to macroeconomics. In the early 1970s, the neo-classical synthesis models combined Keynesian short-run rigidities with classical long-run monetary neutrality. However, with the advent of the rational expectations revolution, these large macro models were deemed to be not well founded in microeconomic behaviour. The model introduced in this paper represents a more rigorous way of combining the classical and Keynesian ideas governing the role of money in the economy. The RBC approach is combined with the New-Keynesian approach which models nominal wage and price rigidities through staggered wage contracts as in Fischer (1977) and Phelps and Taylor (1977). The result is a dynamic general equilibrium model with rigorous microeconomic underpinnings, which features optimization based on rational expectations. The model, however, does deviate from the Walrasian framework of full price and wage flexibility by featuring nominal wage contracts, thereby successfully combining short-term Keynesian dynamics with long-run monetary neutrality. The theoretical model developed here is estimated and simulated using Canadian data.

The remainder of this paper is organized as follows. Section 2 presents a brief empirical investigation of the effect of money on aggregate variables in the economy providing a context for the popular intuitive view that money shocks have some short-run, but no long-run impacts on most aggregate variables in the economy. Section 3 introduces a theoretical model of the macroeconomy that can replicate the empirical evidence of section 2. The quantitative results of the model are reported in section 4. Conclusions are offered in section 5.

2. Empirical Evidence on Money in Canada

Consistent with the rational expectations revolution of the 1970s, several empirical studies emerged which focused on testing the effects of unanticipated money shocks on output. According to theoretical rational expectations models, unanticipated money growth had significant real effects on the economy, and empirical studies began to develop means to test this hypothesis. In that vein, papers by Barro (1978) and Barro and Rush (1980) shed new light on the role of money in the economy. In these papers, the growth in the money aggregate (M1) was dissected into anticipated and unanticipated components by using a univariate regression specified in logarithms. The unanticipated shocks, which are the residuals from the univariate regression equation of money on its lagged values, are used as an explanatory variable in regression equations on output. Through this methodology, Barro (1978) was able to establish a positive and significant effect of unanticipated money growth on output.

In this section, the role of unanticipated money growth on key macroeconomic variables is investigated for the 1960-1992 period in Canada. In an empirical specification similar to the one developed by Barro, unanticipated money shocks are used as an explanatory variable for output, consumption, investment, interest rates, and hours worked. Through the use of contemporaneous and lagged values, a response of economic variables to unanticipated money growth can be constructed. This empirical analysis, showing the response of various economic variables to money shocks found in this section, is then used to evaluate the predictions of the theoretical model developed in section 3.

Determining money shocks

In order to divide money growth into its anticipated and unanticipated components, the following equation, estimated by OLS, tests the common view that there exists persistence in money growth.

$$\Delta \log(M_t) = \beta_o + \beta_1 \Delta \log(M_{t-1}) + \varepsilon_{m,t}$$

where $\varepsilon_{m,t}$ i.i.d. $(0,\sigma_m^2)$, and M_t is taken as real M1 (which is simply M1 deflated by the GDP deflator). The regression parameter values are (t-statistics in parentheses):

$$\Delta \log(M_t) = \underset{(4.6)}{0.003} + \underset{(2.2)}{0.35}\,\Delta \log(M_{t-1})$$

$R^2 = 0.12$; Adj. $R^2 = 0.11$; D-W = 2.04; SSR = 0.05

The results suggest persistence in money growth. Transforming this monetary rule into a rational expectations framework, agents in the economy use the results of this analysis before the beginning of each period and form expectations about what they expect money growth to be. If the agents use the correct money growth rule (and it is assumed that they do, since they are *rational*) then they will be able to anticipate money growth based on historical observations and on the posited money growth rule. There will be a component of money growth that can not be predicted by the agents, however. This will be the unanticipated part of money growth (which is the residual from the above regression), and since the residual is assumed to be white noise, the expectation of this unanticipated shock will be zero. Of course, the actual realization of these shocks can differ from zero in every period.

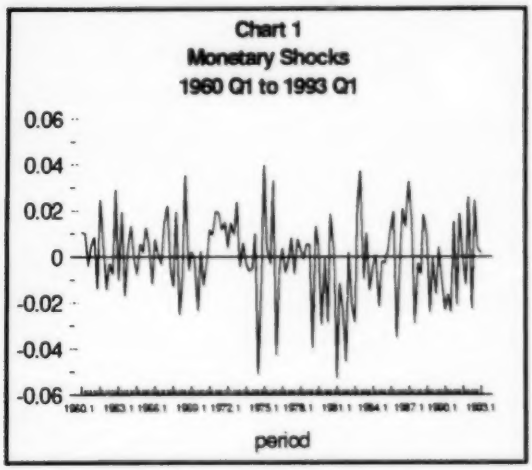


Chart 1 shows the unanticipated shocks taken as the residuals from the estimated univariate regression of money over the 1960 Q1 to the 1993 Q1 period in Canada. These shocks are evenly distributed around zero with a standard deviation of 0.02. It is important to note that, based on this framework, no historical observation can help in predicting the next period's unanticipated shock, which will always be expected to be zero.

In the following, these unanticipated money growth shocks are used to determine their effect on key variables in the Canadian economy based on the following regression equation:

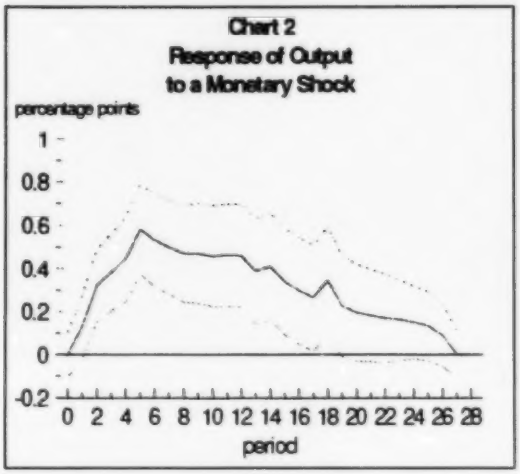
$$\Delta \ln x_t = c + \sum_{h=0}^{27} \Omega_h^x (\varepsilon_{m,t-h} - \varepsilon_{m,t-h-1}) + \Delta\zeta_t^x$$

$$\zeta_t^x \, i.i.d. (0, \sigma_\zeta^2)$$

where c is a constant. The equations are independently estimated for each x, which is output, consumption, fixed capital investment, nominal interest rates, and person hours.

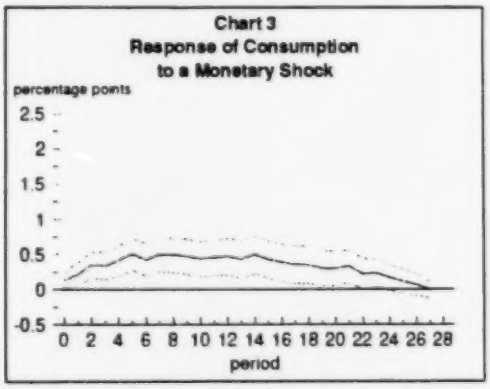
Output and unanticipated money

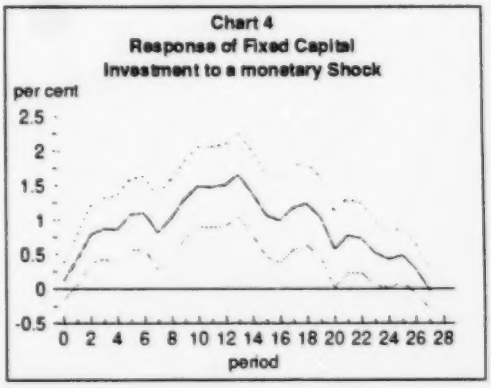
The resulting regression of output growth on lagged unanticipated money growth yields a familiar triangular response which peaks at the fifth to sixth quarter after the shock and dissipates only after a lengthy 20 quarters. Although the contemporaneous effect on output is not significantly different from zero, the results point to positive and significant effects over much of the 27 period lag considered. The effect of unanticipated money growth on output remains significant (at the 95% confidence interval) until the 18th quarter.



This triangular response corroborates similar findings by Barro (1980) and more recently King (1991) for the U.S.. However, in the sense that the effects take over 16 quarters to dissipate, the results found here point to significantly more persistent monetary effects in Canada. Therefore, there seems to be some support to the consensus established since the early 1970s that a positive unanticipated money shock has a positive and persistent effect on output.

Investment, consumption and unanticipated money





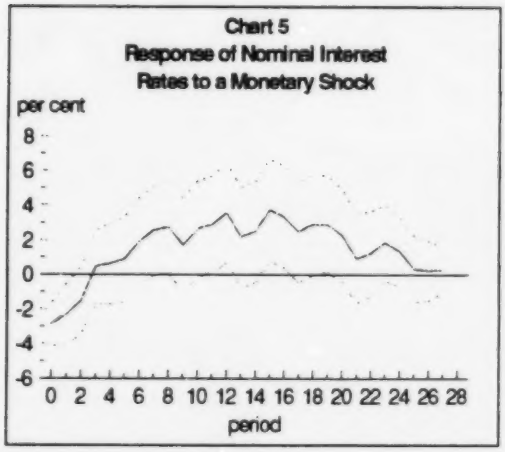
Similar to the effect on output, consumption seems to be characterized by a triangular response to money shocks with a less pronounced peak that occurs between the eighth and tenth quarters. Consumption, however, seems to be slightly less responsive to money shocks than

output, but with a similar lag. This result seems to be consistent with the findings of King (1991) for the U.S., although King finds a significantly lower amplitude of consumption relative to output (about one third).

Fixed capital investment, on the other hand, seems to have the largest volatility in response to an unanticipated money shock. Although the triangular response is again evident, investment seems to have an amplitude around three times as large as output. This result is consistent with the one obtained by King (1991) for the United States, and conforms to the stylized facts in the literature that point to highly volatile investment relative to output.

Nominal interest rates and unanticipated money

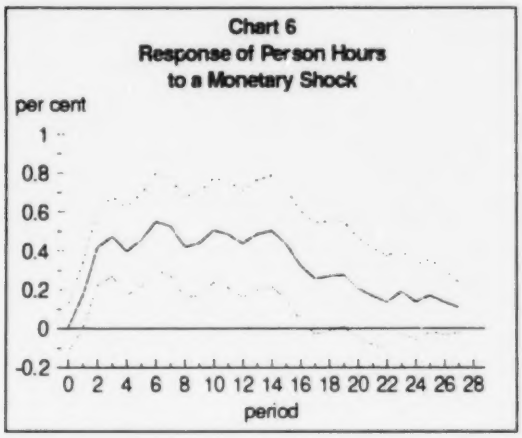
The view on the relationship between nominal interest rates and monetary policy holds that, in response to a positive shock to the money supply, nominal interest rates would initially decline. This immediate drop in interest rates has been alluded to as the *liquidity effect*. Whereas nominal interest rates are expected to drop immediately after such a shock, they increase later due to an expected inflation effect generated by increased money growth. By regressing nominal interest rates on money growth, it is found that the empirical analysis undertaken here confirms this hypothesis.



Although nominal interest rates decline between the first and third quarters, a triangular response follows. The results of the regression, therefore, seem to be suggestive of the existence of the liquidity effect and of the dominance of the expected inflation effect after a short period following the increase in the money supply. As is the case with investment, consumption, and output, the results are significant up to the 18th quarter.

Person hours and unanticipated money

A triangular response can be found in employment in reaction to a money growth shock. With an amplitude very similar to that of output, person hours display a response similar to the one found for the United States by King (1991).



Again, the peak of the triangular-shaped response seems to be in the sixth quarter, and the effect dissipates very slowly. Whereas person hours display a triangular response to money growth shocks, it is probably not surprising that the response of person hours is closely associated with the reaction of output to the same shocks. This is due to the close association between employment and output.

General conclusions from the empirical evidence on money

Although it is not the intention of this paper to solely focus on the empirical treatment of the effects of monetary policy on economic activity, this section has offered some evidence emerging from regressions of a vector of dependant economic variables on lagged unanticipated money shocks. The results seem to confirm the established conjecture that key economic variables are characterized by a triangular response to money growth shocks. In what follows, the paper turns to constructing a theoretical model that is capable of replicating these effects.

3. A General Equilibrium Model with Contracts

The model constructed here is one that contains wage rigidities in the short run, but is independent of the effects of nominal shocks on real variables in the long run. This section contains two parts: the first defines a real business cycle model with exogenous technology and fiscal shocks similar to the one introduced by Christiano and Eichenbaum (1992); the other appends to the real model monetary variables and nominal wage rigidities of the type introduced by Fischer (1977) in a fashion analogous to that adopted by King (1991).

The real business cycle model

Consider a model of the economy with a large number of identical infinitely lived agents. Since all agents are identical, we can characterize the problem of a representative agent with a specified utility function, a set of constraints that this agent faces, and a production function that describes the economy's overall production. Specifically, consider the following maximization problem. The representative household is postulated to maximize utility over the infinite horizon by controlling its consumption and leisure (alternatively, controlling leisure can be thought of as controlling the work hours the agent supplies in the labour market). This maximization problem can be represented as

$$E_o \sum_{t=0}^{\infty} \beta^t \left[u(C_t, G_t, L_t) \right]$$

where C denotes private consumption; G denotes consumption of a public good provided; L denotes leisure; β is a discount factor bounded by zero and one; E_t is an expectations operator at time t; and u is a well behaved utility function (i.e. $u_i>0$, $u_{ii}<0$) satisfying the Inada conditions.[1] Leisure in this model is measured as time spent away from work. Assuming that the household's total time endowment is normalized to a total time endowment T, leisure can be written as $L_t=T-N_t$, where N_t is the labour supplied by the household.

Production in the economy is assumed to be represented by

$$Y_t = f(N_t X_t, K_t)$$

where Y_t is the economy's output given the labour and capital inputs, N_t and K_t. X_t represents the growth of (Hicks neutral) labour-augmenting technical change, taken to be stochastic rather than deterministic. It is therefore assumed that,

$$X_t = \exp(\gamma + \upsilon_t) X_{t-1}$$
$$\upsilon_t = \rho_\upsilon \upsilon_{t-1} + \varepsilon_{\upsilon t}$$

where $\varepsilon_{\upsilon t}$ is i.i.d. $(0, \sigma_\upsilon^2)$, and $0 \le |\rho_\upsilon| \le 1$. Capital accumulation in this economy follows

$$K_{t+1} = I_t + (1-\delta)K_t$$

[1] These are: $u(0)=0$; $u_i(0)=\infty$; $u_i(\infty)=0$; where u_i is the first derivative with respect to both arguments of the utility function.

where I_t is the amount invested at time t, and $0 \leq \ddot{o} \leq 1$ is the capital depreciation rate.

After observing shocks to technology and government spending, the agent chooses her inter-temporal consumption and investment to maximize her utility over an infinite horizon. That is, K_t is taken as a state variable, and X_t and G_t are taken as exogenous shocks, while C_t and K_{t+1} are the control variables that the agent chooses to maximize utility. In this economy, labour markets clear, and the agent's problem becomes one of maximizing the objective function subject to constraints, and according to the goods market clearing constraint

$$Y_t = C_t + I_t + G_t$$

To solve this model, functional forms for utility and production have to be assumed. It is assumed that production can be adequately described by a Cobb-Douglas specification.

$$Y_t = (K_t)^{1-\alpha}(N_t X_t)^{\alpha}$$

where α is labour's share in production. The utility function is assumed to be described by the form

$$u(C_t, T-N_t) = \log(C_t + \kappa G_t) + \theta(T-N_t)$$

This model incorporates the *indivisible-labour* feature introduced by Hansen (1985) where workers face an "all or nothing" labour constraint: workers can only work a fixed amount of hours rather than have the flexibility of choosing their hours. The public good is related to the private good through the parameter κ, which measures the degree of substitutability between private consumption and the consumption of the publicly-provided good. Two interesting cases can be noted. First, if κ is equal to one, then the public good is a perfect substitute for the private good, and the agent reduces consumption at a one-to-one ratio for every unit increase in the public good. If κ is equal to zero, on the other hand, then the public good is not a substitute for private consumption, and the public good will not appear in the individual utility function.[2] The later case of κ equal to zero is taken to be the case in this paper. Therefore, as far as the individual agent is concerned, government will remove a stochastic amount of resources each period. Finally, assume a law of motion for the government consumption shock $g_t = G_t/X_t$ that is of the form:

[2] This in no way implies that governments should not supply the good. The provision of the public good may increase social welfare as it could still enter a social welfare function. This welfare effect, however, is not considered in this framework.

$$\ln(g_t) = (1-\rho_g)\ln(g) + \rho_g(\ln(g_{t-1})) + \varepsilon_{gt}$$

where g is the unconditional mean of g_t, and $0<|\rho_g|<1$, and ε_{gt} is i.i.d. $(0,\sigma_g^2)$.

This system can be solved for the social planner's problem which is equivalent to the competitive equilibrium in this framework. Decision rules for consumption and capital accumulation can therefore be found by setting up the first order conditions for a maximum. Denoting the Lagrange multiplier by Λ, the social planner's problem is

$$\max E_o \sum_{t=0}^{\infty} \beta^t \left[\ln(C_t) + \theta(T - N_t) + \Lambda_t (K_t^{1-\alpha}(N_t X_t)^{\alpha} + (1-\delta)K_t - K_{t+1} - C_t - G_t)\right]$$

Since X_t is defined as a trend, we transform the variables to stationary variables. Therefore $c_t=C_t/X_t$, $k_t=K_t/X_{t-1}$, $y_t=Y_t/X_t$ and $\lambda_t=\Lambda_t X_t$. By dividing K_t by X_{t-1}, k_t remains predetermined. Rewriting the Lagrangean:

$$\max E_o \sum_{t=0}^{\infty} \beta^t \left[\ln(c_t) + \ln(X_t) + \theta(T - N_t) + \lambda_t (k_t^{1-\alpha} N_t^{\alpha} \exp[(\alpha-1)(\gamma+\upsilon_t)] + (1-\delta)\exp(-\gamma-\upsilon_t)k_t - k_{t+1} - c_t - g_t)\right]$$

The Euler equations are then:

$$\begin{aligned}
c_t^{-1} - \lambda_t &= 0 \\
-\theta + \lambda_t \alpha k_t^{1-\alpha} N_t^{\alpha-1} \exp[(\alpha-1)(\gamma+\upsilon_t)] &= 0 \\
-\lambda_t + \beta E_t \lambda_{t+1}\left[(1-\alpha)k_{t+1}^{-\alpha} N_{t+1}^{\alpha} \exp[(\alpha-1)(\gamma+\upsilon_{t+1})] + (1-\delta)\exp(-\gamma-\upsilon_{t+1})\right] &= 0 \\
k_t^{1-\alpha} N_t^{\alpha} \exp[(\alpha-1)(\gamma+\upsilon_t)] + (1-\delta)\exp(-\gamma-\upsilon_{t+1})k_t - k_{t+1} - c_t - g_t &= 0 \\
\lim_{t\to\infty} \beta^t \lambda_t k_{t+1} &= 0
\end{aligned}$$

A non-stochastic steady state will exist in term of these variables, as they have all been divided by the common growth component, X_t. A standard way to solve for a steady state would be to remove the time subscripts and solve the Euler equations and set $\upsilon_t = 0$. This gives:

$$c^{-1} - \lambda = 0$$

$$-\theta + \lambda\alpha k^{1-\alpha} N^{\alpha-1} \exp[(\alpha-1)\gamma] = 0$$

$$-\lambda + \beta\lambda\left[(1-\alpha)k^{-\alpha} N^{\alpha} \exp[(\alpha-1)\gamma] + (1-\delta)\exp(-\gamma)\right] = 0$$

$$k^{1-\alpha} N^{\alpha} \exp[(\alpha-1)\gamma] + (1-\delta)\exp(-\gamma)k - k - c - g = 0$$

Simple manipulation of the above steady state Euler equations give the following relationships between the steady state variables and the parameters:

Output capital ratio: $$\left(y/k\right) = \left[\beta^{-1} - (1-\delta)\exp(-\gamma)\right]/(1-\alpha)$$

Capital-labour ratio: $$\left(k/N\right) = \left[\frac{\beta^{-1} - (1-\delta)\exp(-\gamma)}{(1-\alpha)\exp[(\alpha-1)\gamma]}\right]^{-1/\alpha}.$$

Clearly, there exists no closed form solution for these Euler equations, and an alternative solution must be postulated. We follow the strategy suggested by King, Plosser and Rebelo (1988), where the Euler equations are approximated by a set of linear equations in the unknowns.[3] Using the solution algorithm described in King, Plosser and Rebelo (1988), and through the use of linear quadratic stochastic optimization techniques, decision rules for the control variables can be written as functions of the state, co-state, and exogenous variables. Therefore, the laws governing the motion of the state variables are defined and can be directly computed. The solution then is complete after specifying a forcing (Markovian) process for the exogenous shocks to the system. This will then enable the computation of the transition paths towards the steady state given the value of the initial state variables at time 0, and given a sequence of exogenous shocks. As a means of testing the prediction of the model, we compute the population moments, the impulse responses and the stochastic simulations of the entire system in response to a series of shocks.

A model with nominal wage rigidity

The model described in the first part of this section was a perfectly flexible real business cycle model with no form of rigidities. In that model, consumption and investment are governed by decision rules depending on the capital stock (the state variable which follows a law of motion derived from the model) and the technology and fiscal shocks (the exogenous variables which follow Markovian processes). There is reason to believe, however, that wages do not adjust

[3] The reader should refer to King, Plosser and Rebelo (1987) for a detailed explanation of the solution algorithm.

instantaneously in reaction to monetary, fiscal, or technological shocks. This may be due to the presence of wage contracts, or more generally due to some persistence in nominal wage setting. Without analyzing *why* such rigidities exist in the labour market, it becomes important to analyze the predictions of dynamic general equilibrium models once these rigidities are incorporated. Presently, wage rigidity is captured by positing a nominal wage contract that workers and firms set in advance. Once the wage contract is no longer binding (i.e. after its expiration), the economy reverts back to its neoclassical fundamentals. Therefore, in developing a model with nominal rigidities, the real business cycle model decision rules are exploited to determine the market-clearing values for wages in a way analogous to Fischer (1977) and King (1991).

First, we add a simple log-linear money equilibrium condition to the above model:

$$\ln(M_t) = \ln(P_t) + \phi \ln(y_t)$$

where M_t is the stock of money, P_t is the nominal price of a unit of output, and ϕ is the income elasticity of money demand. Note that the money equilibrium condition abstracts from the nominal interest rate sensitivity of money demand, and velocity is constant.

Next, contracts for wages in the future are set at the present time. That is, the nominal wage at time t+s is set at time t, and is the rational expectation of the wage that will clear the market at time t+s. Under such a scenario, the demand-determined labour input at time t requires that:

$$\ln({}_{t-s}W_t) = \ln(P_t) + \ln(MPN_t)$$

where ${}_{t-s}W_t$ is the notation for nominal wage at time t set at time t-s, and MPN_t denotes the marginal product of labour. In this model, prices are assumed to be flexible. It can be seen that the pre-determined nominal wage contains a powerful channel where money can affect real activity, provided that firms operate along their short-run demand schedules for labour. Combining the wage equilibrium condition with the money equilibrium condition above, and the Cobb-Douglas production function, gives the following relations:

$$\ln(N_t) = \left[\frac{\ln(M_t) - \ln({}_{t-s}W_t) + \ln(\alpha) + (1-\phi)(\alpha-1)(\gamma+\upsilon_t) + (1-\phi)(1-\alpha)\ln(k_t)}{[1-\alpha(1-\phi)]} \right]$$

$$\ln(y_t) = \left[\frac{\alpha\left(\ln(M_t) - \ln({}_{t-s}W_t) + \ln(\alpha)\right) + (\alpha - 1)(\gamma + \upsilon_t) + (1-\alpha)\ln(k_t)}{\left[1 - \alpha(1-\phi)\right]} \right]$$

where N_t is labour; k_t is capital; y_t is output; and α is the labour share of production. The equations reveal the dynamics in which money affects output and employment.

In this model, wages evolve over time according to the rational expectations that equate labour demand and labour supply. These are wages that would prevail in the *real* model at time t+s given that capital is accumulated according to the *sticky wage* model. Therefore, wages evolve according to:

$$\ln ({}_t W_{t+s}) = E_t \ln(P_{t+s}) + E_t \ln(MPN^*_{t+s})$$

where MPN^*_{t+s} is the market-clearing marginal product which can be derived from the real model, and which characterizes the market-clearing operation of the economy. Capital evolution is rationally-expected to be determined by the model with wage rigidities during the period under which the contract is in effect. Similar to King (1991), this is a two regime model where the dynamics of the model are neoclassical in the long run, while the quantities are determined in the short run on the basis of the Keynesian nominal wage rigidity model described here.[4]

The model is closed by positing the following law of motion for money growth:

$$\ln(m_t) = (1-\rho_m)\ln(m) + \rho_m(\ln(m_{t-1})) + \varepsilon_{mt}$$

where m is the unconditional mean of m_t, and $0 < |\rho_m| < 1$, and ε_{mt} is i.i.d. $(0, \sigma^2_m)$.

The above model can be interpreted as a staggered wage model where wage contracts are set to the expected market-clearing conditions in the terminal contract periods, but follow the set nominal wage during other periods where there is a pre-existing wage. Based on empirical findings on nominal wage rigidities in Canada,[5] it is assumed that sixteen period staggered contracts are prevalent, and that each period one-sixteenth of the existing contracts come up for re-negotiation. Therefore, after a shock hits the economy, only one-sixteenth of the labour market every period can react to the new environment. Obviously, the labour markets does not clear in such a model, and labour is faced with a situation where nominal wages differs from the marginal product. This

[4] See Appendix A.
[5] See for example, Mang (1994).

distinction transforms the model into a non-Walrasian framework where wages do not adjust immediately to clear the labour market, although prices adjust instantaneously. The results are based on an averaging of the agents with and without contracts.

4. Results from the Model[6]

The above model captures the conjecture that wages may be slow to adjust, contrary to the standard new-classical assumptions. Theoretically, the model was able to provide a channel of the effects of monetary policy on labour, output and therefore consumption and investment. Monetary policy is effective when workers are bound by contracts, and reverts to long-term neutrality when contracts expire. To assess the effect of monetary policy, the model is fully parameterized so that the path of decision variables can be traced. The following parameter values are assigned to the theoretical model.

Parameter	Description	Value
α	labour share	0.66
β	subjective period discount factor	$(1.03)^{-0.25}$
δ	depreciation rate	0.02
ϕ	income elasticity of money	0.5
κ	substitutibility of government and private investment	0
γ	trend productivity growth	0.006
θ	leisure substitutability	0.007
ρ_g	persistence in government spending	0.91
σ_g	standard deviation of government spending	0.02
σ_υ	standard deviation of technology shock	0.02

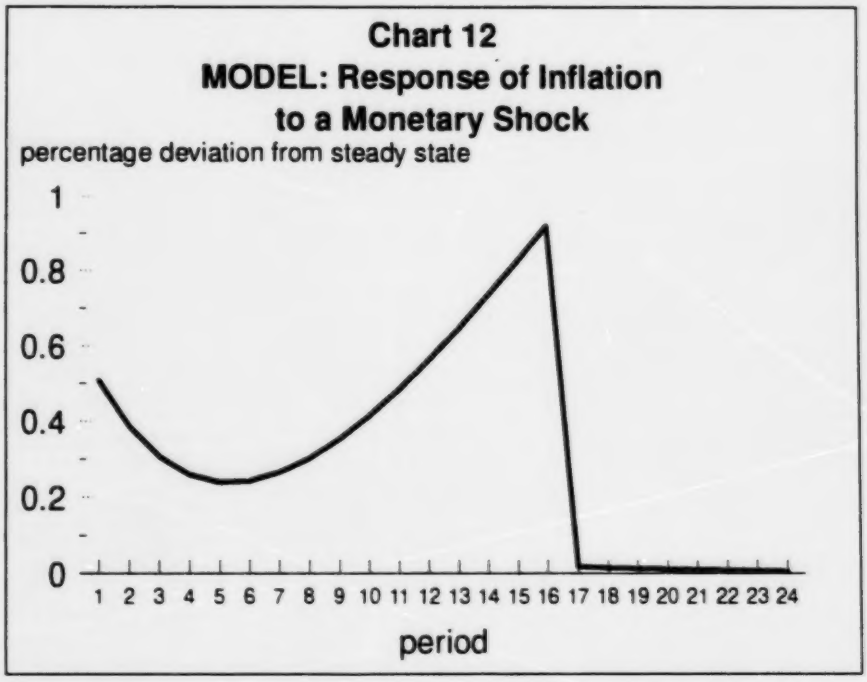
At present, we are interested in evaluating the impact of monetary policy within the framework of the model. Real business cycle literature has traditionally focused on matching first and second moments of the data generated by the model with observed data in the economy, however, an alternative route is to try to replicate impulse responses. Since it is of interest to trace the short-term and long-term effects of monetary policy, the current analysis focuses on measuring the responses of various variables in reaction to an expansion of the money supply. The

[6] Data sources are described in Appendix B. The Canadian data set is available from the author upon request.

assumption is that nominal wages in the economy are set for sixteen periods and contracts are staggered as in Fischer (1977). In what follows are the predictions of the model for inflation, labour input, investment, interest rates and output in reaction to a 1% increase in money supply over 16 periods.

Inflation

Since prices are assumed to be flexible, the first impact of the money shock is to directly raise the price level in the economy which is consistent with the final model solution for prices that clear the goods market in response to the money shock. As a result, the rate of inflation rises initially by 0.6 percent. However, as the monetary expansion remains persistent, the rate of inflation peaks at 1 percentage point above its steady-state level. When the economy returns to the neoclassical paradigm, and as monetary policy ceases to play a role, inflation quickly drops to its steady-state level. The model, therefore, predicts that an expansionary monetary policy increases the rate of inflation. However, there are no permanent effects of monetary policy on inflation.

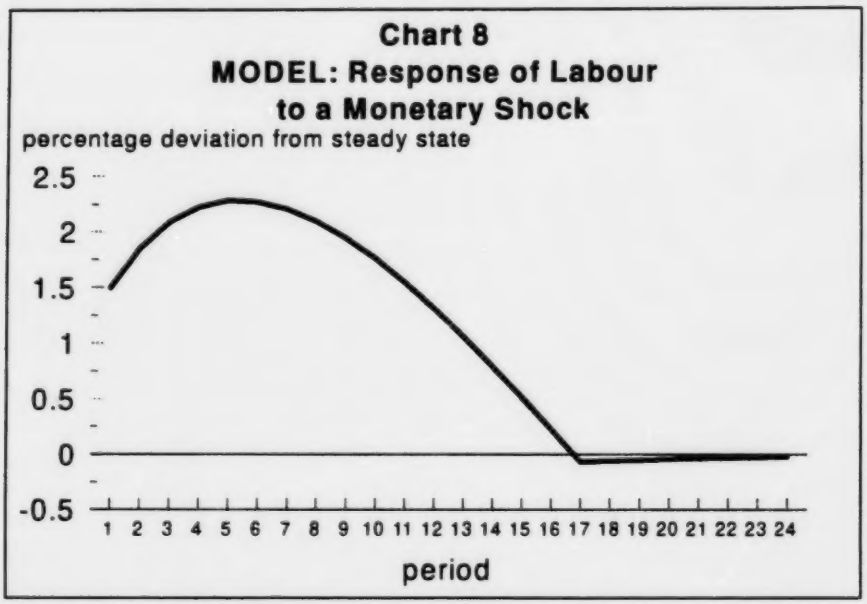


With prices increasing, and nominal wages remaining fixed due to the presence of contracts, real wages in the economy fall due the money shock. Therefore, this increase in prices

represents the primary effect of monetary policy on the economy, and sets into motion a chain of events that has implications for labour input, consumption, investment, interest rates, and output.

Labour

Since employment in the short run is demand-determined in this economy, the fall in real wages due to the price increase stimulates demand for the labour input. As a result, employment increases by around 1.5 percent in the first period since the Keynesian paradigm is in full effect. By the second period, increased capital accumulation increases labour input, but the effect is countered by a growing fraction of workers reverting to the neoclassical model after the expiry of their contracts.

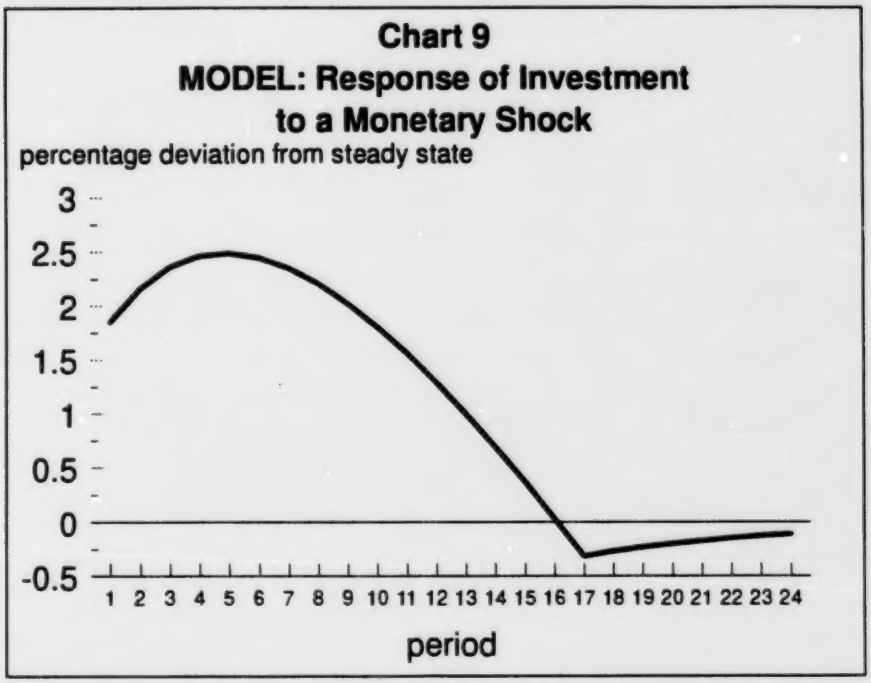


Although in the short-run, labour input is demand-determined, as contracts expire, labour input returns to being supply-determined. After the expiry of contracts, labour supply declines in reaction to the new lower wage level. Eventually, labour supply reverts back to its steady state. As a result, the model is able to replicate the triangular response captured in section 2.

Investment

Investment is a key variable in this "hybrid" model. With increases in employment due to the money shock, expectations of further increases of labour input over the remaining period of the pre-set contracts result in increases in capital investment due to the complimentarity of labour and

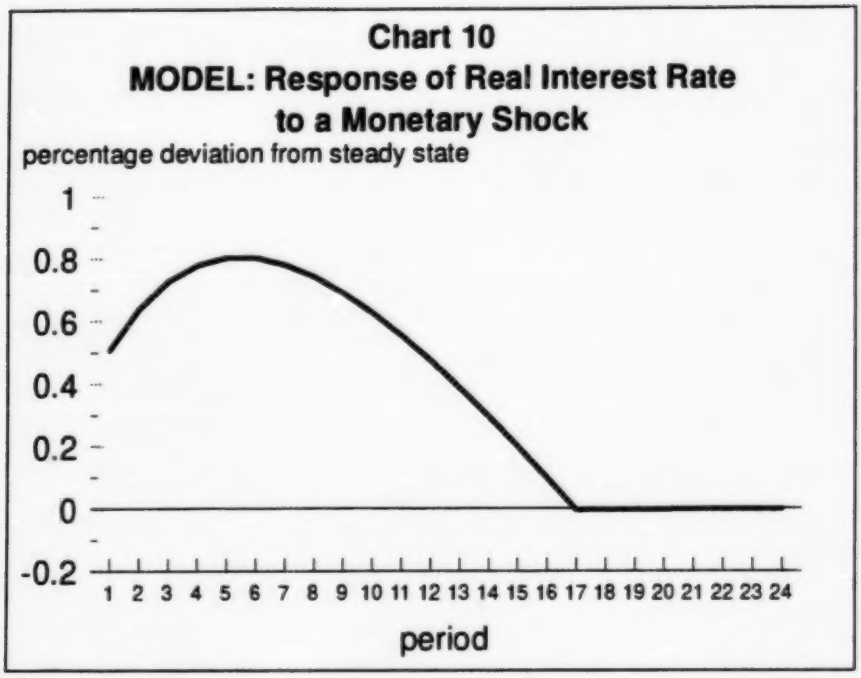
capital. As the model switches to a neoclassical paradigm after the expiry of the wage contracts, capital is at a level higher than that given by the neoclassical fundamentals. The result is a sharp decrease in investment to allow capital to revert to its steady-state level. The capital stock adjusts to its initial level, as investment reverts back to its steady-state level.



This mechanism, however, provides a long and persistent effect of monetary policy that affects investment positively while the contracts are in effect (i.e. in the short run) while having a negative effect in the medium-term, and no effect on the steady-state level. An important feature of the model is that it is successful in providing a large impulse response of investment to the money shock. This is consistent with the stylized facts concerning the volatility of investment, and also consistent with the distributed-lag regression results presented earlier.

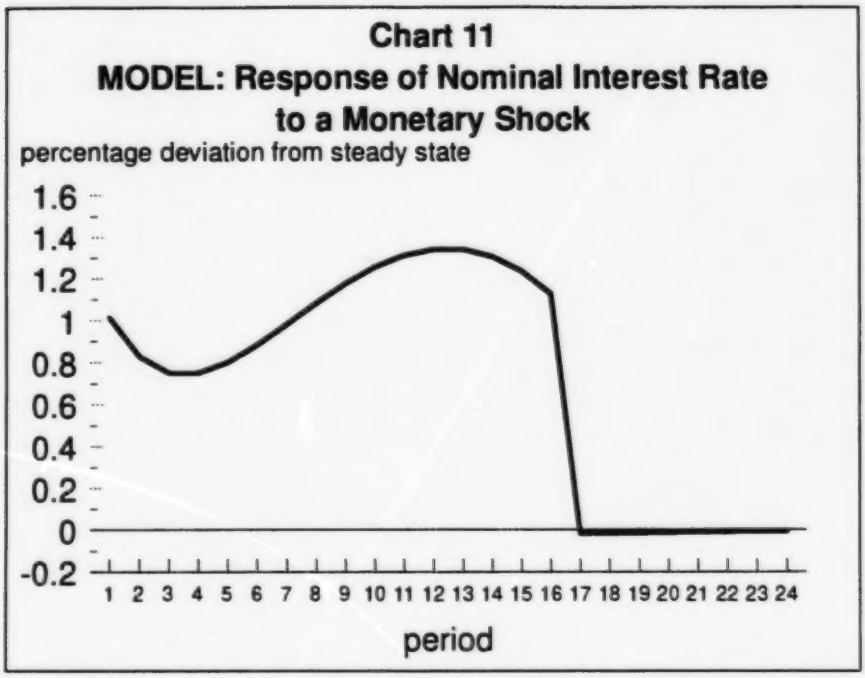
Interest Rates

The model predictions with respect to interest rates are mixed. First, the model predicts an increase in the real rate of interest in the short-run -- consistent with the result found by King (1991) for the U.S., because of the prolonged period of wage stickiness and its effect on the future expectation of capital productivity.



The expectations raised by a persistent money shock increases the demand for labour input. Since capital and labour are complementary, there are expectations that the marginal productivity of capital will increase in the future, thereby increasing investment and interest rates. This channel appears to be strong enough in the model so that it over-powers the negative effect on interest rates from increased savings (which usually follows from consumption smoothing behaviour in the presence of temporary increases in output).

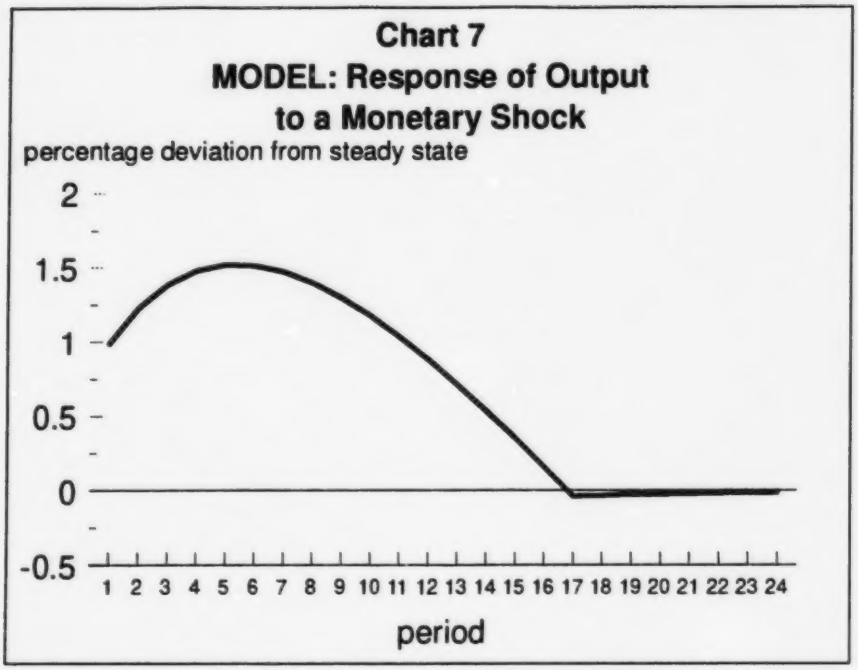
Nominal interest rates, on the other hand, tend to react positively to the increase in the money supply throughout the entire period governed by nominal wage contracts. As such, the model predicts an increase in nominal interest rates of just over one percent in the first period following the expansion in the money stock. Although nominal interest rates start to decline as the model moves to neoclassical fundamentals, the expected inflation effect is dominant throughout the period where the Keynesian paradigm is in effect. In this respect, the model cannot generate a liquidity effect of nominal interest rates in reaction to an increase in the money stock. In the context of the model contained here, the expected inflation effect is dominant and ensures an increase in nominal rates.



As the economy switches totally to the neoclassical paradigm after the expiry of all the wage contracts, the nominal interest rate returns to its steady-state level. The move to the neoclassical paradigm is characterized by a sudden drop in interest rates due to the cessation of the role of monetary policy in the neoclassical economy.

Output

In response to an expansion in the money supply, labour input and investment increase causing output to initially increase by approximately 1 percent. After the initial impact, capital begins accumulating according to the Keynesian paradigm, having a secondary upward effect on output starting in period 2. As one-sixteenth of the contracts expire every period, that fraction of workers no longer bound by the wage contracts follows the neoclassical fundamentals in setting their future wages, and the total effect on the aggregate economy is an averaging of output based on the portion of workers in each of the two paradigms.



As more and more contracts expire, the economy moves more towards the neoclassical paradigm, with consumption, capital, labour and output returning to steady-state levels. Since the economy obeys a Keynesian capital accumulation rule during the period of the contracts, the economy starts from a position of too high a capital stock compared to the steady-state relationship dictated by the neoclassical model. The response of the real model after 16 periods is to lower the level of capital through increased consumption, causing a slight decrease in output starting in period 16. Eventually, the model reverts back to its steady-state level of output as capital slowly adjusts. This process of switching between the two regimes, the Keynesian when the contracts are in effect, and the neoclassical when the contracts expire, provides a triangular shape response of output to an expansion in the money supply, similar to the one observed in the distributed lag regression in section 2 of the paper.

5.0 Conclusions

This paper combines the real business cycle model of Christiano and Eichenbaum (1992) with the nominal wage contacts model first introduced by Fischer (1977) in a manner analogous to the one used by King (1991). Deviating from the strict wage flexibility framework of the real business cycle model, by introducing nominal wage contracts, we are able to produce a model

whose predictions match the view that money is non-neutral in the short run in its effects on output, labour input, consumption, investment and interest rates. The model produces neoclassical results in the long-run. In essence, detaching the model from full wage flexibility enhances its predictions regarding the short-term effects of money on real variables. To the extent that such nominal wage rigidities exist in the Canadian economy through explicit and implicit wage contracts, the model contained in this paper provides an important insight into the effect of monetary policy in Canada.

Several issues remain unresolved, however. First, extensions of this line of research will inevitably have to answer the question as to *why* nominal wage and price rigidities exist. Second, a common failing of nominal wage general equilibrium models tends to be that they cannot replicate the liquidity effect for interest rates due to the strong anticipated inflation effects contained in the wage setting mechanism. Although RBC papers have begun to emerge featuring modified cash-in-advance constraints that can replicate the liquidity effect, it is not clear that this innovation in modelling can be incorporated into a model with nominal rigidities. An important area of exploration will then be the incorporation of a monetary transmission mechanism that will account for rigidities, while maintaining a short-term liquidity effect sufficiently great to offset the anticipated inflation effect of monetary expansion.

Incorporating nominal wage rigidities seems to provide encouraging results. Using Canadian data, we have shown that a stochastic general equilibrium model with wage rigidities performs well, and corroborates the U.S. results. More importantly, this branch of research has brought together attractive elements from both the New-Keynesian and New-classical agendas. Hopefully, this will be a recipe for more insightful economic models of the macroeconomy in the future.

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APPENDIX A

The following laws of motion and decision rules can be computed from the real model:

The state variable:

$$k_{t+1} = \pi_{kk} k_t + \pi_{kv} v_t + \pi_{kg} g_t \ .$$

The co-state variable:

$$\lambda_t = \pi_{\lambda k} k_t + \pi_{\lambda v} v_t + \pi_{\lambda g} g_t \ .$$

The control variables:

$$c_t = \pi_{ck} k_t + \pi_{cv} v_t + \pi_{cg} g_t$$
$$N_t = \pi_{Nk} k_t + \pi_{Nv} v_t + \pi_{Ng} g_t$$

Other variables of interest:

$$y_t = \pi_{yk} k_t + \pi_{yv} v_t + \pi_{yg} g_t$$
$$\omega_t = \pi_{\omega k} k_t + \pi_{\omega v} v_t + \pi_{\omega g} g_t$$
$$i_t = \pi_{ik} k_t + \pi_{iv} v_t + \pi_{ig} g_t$$
$$r_t = \pi_{rk} k_t + \pi_{rv} v_t + \pi_{rg} g_t$$

where

y denotes output;
ω denotes labour productivity;
i denotes investment; and,
r denotes rate of return on capital.

The above decision rules describe the evolution of the variables of the artificial economy based on observed values of the state variable, and the technological shocks.

In the nominal model, wage contracts are set *s* periods in advance based on the expected market clearing wages. That is

$$\ln ({}_{t-s}W_t) = \ln(P_t) + \ln(MPN_t)$$

where MPN_t is the marginal product of labour. Replacing $\ln(P_t) = \ln(M_t) - \phi \ln(y_t)$, and replacing the value for MPN_t from the real model and iterating yields the following relationship (expressed in percentage deviation from the steady state:

$$E_t W_{t+s} = \rho_m^s \hat{m}_t + \left[(1-\phi)\pi_{yv} - \pi_{Nv}\right]\rho_v^s \hat{v}_t + \left[(1-\phi)\pi_{yg} - \pi_{Ng}\right]\rho_g^s \hat{g}_t +$$

$$\left[(1-\phi)\pi_{yk} - \pi_{Nk}\right]\pi_{kk}^s k_t + \sum_{i=1}^{s}\left[(1-\phi)\pi_{yk} - \pi_{Nk}\right]\pi_{kk}^{i-1}\pi_{kv}\rho_v^{s-i}\hat{v}_t +$$

$$\sum_{i=1}^{s}\left[(1-\phi)\pi_{yk} - \pi_{Nk}\right]\pi_{kk}^{i-1}\pi_{kg}\rho_g^{s-i}\hat{g}_t$$

This dynamic wage contract will then be agreed upon by the workers and the firms. When the workers are bound by the contract, the nominal wage agreed upon s periods in advance will be the one paid, and the labour input ad output will be given accordingly.

APPENDIX B

Data Sources and methodology: (All data except interest rates and time endowment, expressed on a per-capita basis).

Consumption: Real consumption on durables and non-durables. National Income and Expenditure Accounts, Quarterly.

Investment: Real private investment and private inventories. National Income and Expenditure Accounts, Quarterly.

Capital: capital stock is one consistent with the investment series above. This is taken from an estimate of the capital stock at the Department of Finance.

Time endowment: Taken form Christiano and Eichenbaum to be 1369 hours per quarter.

Hours worked: Quarterly hours worked in the manufacturing sector. Non-published series.

Government Spending: Real government spending on investment, goods and services and inventories.

Output: Sum of consumption, investment, and government spending. This will correspond to real GDP minus net exports.

Steady-State Real Interest Rate: Assumed to be 3 percent per annum.

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